AD-774 833

METHOD FOR HUMAN FACTORS EVALUATION OF BALLISTIC PROTECTIVE HELMETS

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September 1973

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AMCMS Code 674713.55.L42

Technical Memorandum 18-73

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AD-774833

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Human Engineering Laboratory Aberdeen Proving Ground, MD 21005	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

METHODS FOR HUMAN FACTORS EVALUATION OF BALLISTIC PROTECTIVE HELMETS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1973	~~48~~ 47	15

8a. CONTRACT OR GRANT NO b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Memorandum 18-73 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AMCMS Code 674713.55.L42

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

Several experiments and surveys were conducted to learn more about the relationship between helmet weight, shape and suspension for ballistic protective helmets. Surveys were conducted to develop rating scales suitable for field testing. Experiments were conducted using the rating scales as the dependent variable. Design guidance and testing methodology are suggested for development and for human factors evaluation for future ballistic protective helmets.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ballistic Protective Helmets Design Guidance for Helmet Development Helmet Weight M1 Helmet Human Factors Engineering						

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EXECUTIVE SUMMARY

1. The objective of this report is to describe methods for performing human factors evaluations of ballistic protective helmets and to provide design guidance for helmet development.

2. a. Under the Five-Year Technical Plan for Personnel Protective Equipment the Human Engineering Laboratory has investigated methods for evaluating ballistic protective helmets. Literature reviews have shown the need for methods to test prototype helmets under dynamic conditions. Present user acceptance data points to weight and instability as being the least acceptable characteristics of the present M1 helmet. Weight is directly related to ballistic protection; therefore, it is important to provide a helmet which is perceived as light but is physically heavy enough to provide good ballistic protection.

b. In order to test candidate helmets against a known reference it was necessary to quantify aspects of the M1 helmet. Rating scales were used to estimate the feelings of the using population towards the M1. These rating scales were tested in controlled experiments and efforts were made to interrelate the scale with physical weight. Additionally, HEL personnel were able to observe users for extended periods of time. From these observations it was possible to conceptualize features which should optimize helmet design.

3. The rating scales were found to be a suitable method of evaluating helmets when administered after dynamic exercise. Repeated use of the rating scales has shown very high reliability in assessing user-acceptance. Factor analysis of rating scale data provided insight into the complex interrelationships of comfort, fit, ballistic protection and appearance. These findings show that differences of opinion exist between officers and NCOs, and lower ranking enlisted men. Soldiers in leadership positions tend to place more emphasis on the ballistic characteristics of helmets while the younger enlisted men are more concerned with comfort variables. Rating scale data shows that the optimum weight for a M1-shaped helmet is between 2.0 and 2.5 pounds.

4. Design guidance is offered. This guidance includes - providing for a well-balanced, sized-helmet system; suspension systems with on-the-head adjustments; consideration of current hair styles; heavy emphasis on helmet stability and retention as opposed to weight reduction and design which minimizes the occurrence of headaches. The findings indicate that the present helmet uses ballistic materials to provide rain protection and a sun visor. This adds to the helmet weight, but offers little additional ballistic protection. The flaring of the front and rear aspects of the M1 helmet causes compatibility problems with the rifle and load-bearing equipment. It was also found that the chin strap does aid in keeping the helmet on the head, but does not prevent disorientation of the helmet during violent movement.

5. Recommendations are made to test candidate helmets from a human factors engineering point of view. This testing should include - mobility, small arms employment, fitting, retention during dynamic conditions, acoustical and visual field testing, compatibility analysis with specific equipment, and user-acceptance considerations.

METHODS FOR HUMAN FACTORS EVALUATION OF BALLISTIC PROTECTIVE HELMETS

GENERAL

INTRODUCTION

Reducing weight has been assumed to be the major consideration in providing a more suitable helmet for the U. S. Army Infantryman. Reviewing information on user acceptance of the M helmet (15) reveals that weight is one of the major complaints about the present device. The Human Engineering Laboratory (HEL) has studied the weight problem in an effort to provide trade-off information for helmet designers.

The concept of weight in helmets must be considered before deciding what physical weight is most appropriate. The human body experiences the sensation of weight when muscle contraction is necessary to support an object. When a soldier wears his helmet in a static condition, his musculature supports the weight generated by the forces of gravity. However, when he moves as soldiers must, additional forces are generated. Inertial forces tend to cause the helmet to lag behind head movements. When the helmet "catches" the head, momentum tends to keep the helmet moving. When the helmet stops, forces are exerted on the head. The human body is not equipped with inertial or momentum receptors so these forces are reported as weight. Therefore, it is reasonable to suggest that some portion of perceived helmet weight can be attributed to forces other than absolute physical weight.

In 1958 Lewis et al. (7) studied the relationship between weight, ballistic protection and rotational forces as a function of helmet standoff. Their findings indicate that as the standoff from the head increases, the rotational forces increase. Further, the findings demonstrate that as standoff increases, the amount of total ballistic surface area coverage of the head remains the same while the total helmet weight increases. This effect can be expressed as a weight efficiency index. He concludes that "It is imperative, therefore, that the radius of the shell (r_s) be as nearly equal to the radius of the head (r_h) as possible." From these observations, it is apparent that standoff and shape are of considerable importance to the total perception of the weight of a helmet.

User acceptance (15) indicate that the infantry soldier is completely aware of these relationships. If weight is the most frequently mentioned complaint about the present helmet, stability is a close second. In fact, the user has been reporting problems associated with helmet stability for a considerable period. Typically, these complaints are associated with the fact that most soldiers do not fasten the helmet chin strap. However, a well-balanced helmet would be easier to stabilize with or without a chin strap.

Only the user can report these effects It is possible to generate mathematical models to estimate the forces, but the combined sensory experience of the forces about the helmet worn by a soldier are available to him alone. Therefore, to learn about the total sensory experience, we must ask the wearer. Unfortunately, there are many words to describe these sensations. Each person has his particular jargon. There is no way to directly equate responses like good, rotten, terrific, fair, lousy, etc. Nevertheless, it is clear that the user is the expert and he has the answers. Those who have questions must find a suitable means of communication with the user.

This report describes a series of experiments and surveys conducted by HEL to learn more about perceived weight of helmets and to develop testing procedures necessary to ask the user to compare future candidate helmets to the present M1 helmet.

The report covers investigations designed to evaluate the individual's ability to detect asymmetrically-distributed weight on the head with the development of a rating scale suitable to use in helmet evaluation, results of an experiment designed to link the rating scale with helmet characteristics in a dynamic setting, and the results of interrelating incremental helmet weight with the helmet rating scales. Design guidance and human factors evaluation (HFE) methodology are recommended.

ASYMMETRICAL WEIGHT DISTRIBUTIONS

INTRODUCTION

Investigations to determine the ability of an individual to judge the amount of weight on the head have shown that symmetrically distributed weight is not easily detected (3, 6). These findings have important implications to helmet design since weight is correlated directly with ballistic protection.

The ability to judge symmetrical distribution of weight in a static condition is but a small part of the much more complicated dynamic condition. If we can assume that any helmet suspension system allows the helmet to move with respect to the head, then it is necessary to consider asymmetrical weight distributions. HEL has conducted an experiment to determine the ability of an individual to judge the location of imbalance on two different helmet forms. The dependent variable in this investigation is the amount of weight necessary for an individual to detect an imbalance in a static condition. The independent variables include the helmet forms and suspension systems.

METHOD

Subjects

Twenty-one enlisted infantrymen, grades E-2 through E-7, served as subjects (S̲s).

Apparatus

Two helmet forms were used during the experiment. The Hayes-Stewart prototype and M1 helmet with liner are equipped with different suspension systems. The Hayes-Stewart weighs 1.5 pounds and employs a polyfoam-pad suspension which can be adjusted by moving or removing the pads about the Velcro mounting material. The M1 helmet weighs 3 pounds 2 ounces and uses the standard suspension system. Both helmets were covered with Velcro material so that lead weights weighing one ounce each could be added according to the experimental plan.

Procedure

Subjects were seated in a straightbacked chair during the experiment. Each subject was first asked to adjust the suspension system of the helmet so that it was comfortable for him. In the case of the Hayes-Stewart helmet the method of adjustment was explained to the individual. After the subject had adjusted the suspension system, he was told to place the helmet on his head as if he were preparing to use the device in the field. At this time, the experimenter marked the subject's ears at a level even with the side edge of the helmet. The neck of the subject was also marked at a point under a rear reference mark on the helmet. This procedure allowed the experimenter to place the helmet on the subject's head at approximately the same place for each trial.

The S was asked to visualize the helmet as being divided into quadrants, i.e., left front, left rear, right front and right rear. He was then told to report any imbalance in terms of these locations. The experimenter then removed the helmet from the S's head and manipulated the balance of the helmet by adding a lead weight to the helmet. The helmet was replaced on the S's head and the reference marks aligned. S was then asked if he could detect and locate any imbalance. The procedure was repeated until S responded correctly twice in a row. In this manner the weight of a given quadrant was increased by one ounce increments until the asymmetrical weight was experienced by the S. The location of each one ounce was predetermined by a standard procedure. This procedure provided that the first increment be placed along the bottom edge of the helmet, at the mid-point of the quadrant being manipulated. The second increment was applied just next to the first increment in the direction of the front/rear designation of the quadrant. The third increment was added next to the first increment but on the opposite side. Other increments were added according to the stated rule, but immediately above the first row. The presentation order of the quadrants was random.

Each S experienced the procedure for both M1 and liner and Hayes-Stewart helmet configurations.

RESULTS

The data were submitted to several statistical analyses. The mean weights in ounces added to each quadrant are displayed in Table 1. The overall mean for the M1 helmet was calculated at 3.9 ounces while the mean Hayes-Stewart weight was 4.1 ounces. The distribution of values was submitted to analysis of variance (Winer). Analysis of variance (ANOVA) with repeated measures across treatments showed a significant difference between M1 and Hayes-Stewart treatments ($p < .05$, $F = 5.37$ df 1/20, Table 2).

TABLE 1

Mean Weights of Detected Imbalance
(Ounces)

	Right Front	Left Front	Right Rear	Left Rear
M1	3.95	4.24	3.43	3.85
Hayes-Stewart	4.62	5.00	3.24	3.62

TABLE 2

ANOVA Summary Table (M1 Versus Hayes-Stewart)

Source	SS	df	MS	F	Sig.
Between Subjects	327	20			
Within Subjects	203	21			
Helmets	(43)	(1)	43	5.37	p .05
Error	(160)	(20)	8		
Totals	530	41			

DISCUSSION

The results of analysis of variance, using total weight in all four quadrants for each subject, by helmets, indicates a difference between the M1 and Hayes-Stewart configurations as far as detection of imbalance is concerned. The overall means for the individual helmets differed by only 0.2 ounces (4.1 - 3.9 = 0.2) The weight distributions for the four quadrants of the individual helmets was the source of the variance.

In comparing the two helmets by quadrants, it is necessary to decide what constitutes a positive input to helmet design. Taking the absolute values of the distribution of weights, the front of the Hayes-Stewart required more weight increments before detection of imbalance occurred. This finding must be considered along with the geometry of the Hayes-Stewart device. The standoff distance for the Hayes-Stewart is less than the M1 standoff because the Hayes-Stewart is a sized system. The fact that more weight was required to produce perceptual imbalance in the forward quadrants indicates that the Hayes-Stewart prototype forward construction is superior to the M1 helmet since the individual's ability to determine imbalance was lowered significantly.

It is possible that shape and suspension system interact with weight to produce the effect of the total helmet system. If so, simply lowering helmet weight will not necessarily yield an equal increment of perceptual weight reduction in helmets with differing suspension systems.

According to psychophysical theory, the individual should be able to detect smaller changes in weight on the lighter Hayes-Stewart helmet. Just the opposite is true. This indicates that the effects seen in this experiment are more pronounced than the data suggest.

The effects of handedness can be seen in the results. Subjects were less likely to detect imbalance on the side of the helmet opposite the handed side. This finding indicates that some slight advantage can be gained by mounting ancillary equipment (radios, headsets, etc.) on the side opposite the handed side of the individual.

Examining the means depicted in Table 1 reveals several interesting relationships. The Hayes-Stewart front-quadrant means are higher than the M1 front-quadrant means. The M1 is manufactured with a visor across the front aspect of the helmet, while the Hayes-Stewart has none. The M1 visor is made of ballistic material which adds length to the radius of the helmet across the front and weight to the total helmet. Evidently, the <u>S</u>s were able to detect this difference. Designers should consider this effect in future helmet configurations.

Table 1 also shows the rear-quadrant means of the M1 are slightly higher than the same quadrants for the Hayes-Stewart. This effect must be attributed to the Hayes-Stewart's longer rear section which provides ballistic coverage to the lower/upper neck area. The differences between M1 and Hayes-Stewart shapes across the rear are considerable. The M1 helmet flares out to keep rain from running down the neck. In effect, this feature provides a counterbalance for the front visor; however, making this flare out of ballistic material is of questionable value since it adds to the overall weight of the helmet without providing an equivalent amount of area ballistic protection. The Hayes-Stewart does provide protection; however, the front-to-rear relationship is more pronounced. That is to say, that the difference in perceptual imbalance, front to rear, for the Hayes-Stewart are (1) right side = 1.42 ounces and (2) left side = 1.38 ounces, while the same relationship for the M1 is (1) right side = .51 ounces and (2) left side = .39 ounces. This finding indicates that the M1 system has better overall balance than the Hayes-Stewart prototype.

CONCLUSIONS

From the findings of this experiment, the following conclusions were drawn:

1. Asymmetrically distributed weight on the head can be detected in the four-ounce range and can be reported as imbalance.

2. Handedness may be a variable in detecting weight imbalances about the head.

3. Front flaring of helmets aids the detection of imbalance.

4. Helmet shape and weight distribution are interactive.

RATING SCALE: VERSION 1

INTRODUCTION

Simultaneously with investigating helmet weight, HEL attempted to measure user acceptance factors which combine to form the overall individual impression of a given helmet. Several methods are available to collect such information. After reviewing the literature it was decided to concentrate development effort on the semantic differential technique (8). This decision was based on the following assumptions: First, the attitudes and opinions of a soldier toward his helmet are very complex. Multivariate relationships cannot be analyzed in terms of percentages or simple yes/no questioning. Some sort of graded responding is necessary. Thus rating scales were indicated. Second, the technique selected must be relatively simple to administer to soldiers. Finally, the technique selected must have a good record of success in predicting user preferences. The semantic differential technique offered the most flexible choice in meeting the needs of the program (12).

Two pilot surveys were conducted to determine if the semantic differential technique was suitable for use in helmet development. Basically, the technique offers the individual a set of bipolar adjective pairs (i.e. Heavy-Light). When presented to the individual, the pairs are separated by several points, spaced equally across the page.

Example:

HEAVY o o o o o o o LIGHT

The individual is instructed to consider the M1 helmet and express his view of the helmet along the seven-point scale. He is instructed to think of the midpoint of the scale as neutrality or no opinion. If he feels the helmet is extremely heavy, he would mark the point closest to the word, "Heavy." If he feels the helmet is moderately heavy, he would select point number 2, etc. This scale provides him with seven choices as far as weight is concerned. When several bipolar adjectives are presented the individual has the opportunity to express his opinions of a number of helmet features (hot-cool, stable-unstable, protective-unprotective). The resulting responses are known as the semantic profile and can be analyzed together so that the relationship between bipolar adjective pairs is expressed.

When large numbers of these responses are collected from different individuals statistical analysis is possible. It is then possible to isolate factors which may exist throughout the total sample. These factors can be ordered in terms of importance. The designer is then in a position to know which aspects of a ballistic protective helmet are most important to the potential user.

HEL attempted to develop a usable rating scale, to analyze the data generated when the scale adopted was applied to a large sample of soldiers, and to draw conclusions from that analysis.

Many of the problems associated with low user-acceptance result from the fact that the likes and dislikes of the user population are not known until the troops are required to use an item in regular military duties. If the opinions and attitudes of the user population were known in advance, the sources of irritation could be minimized in the design stages, a procedure which should result in better troop acceptance.

The application of the semantic differential to human factors research, specifically to the evaluation of helmets, offers many possibilities if a scale can be developed to isolate attitudes towards equipment of interest. If an appropriate scale can be developed, the collection of large blocks of data could be achieved, since the technique employs a group pencil-and-paper testing procedures (A typical scale can be administered by an untrained proctor in less than 15 minutes).

The purpose of the first survey was to determine the feasibility of using the semantic differential as an aid to equipment design and evaluation, and to define regularities which exist in evaluative criteria of the user population. Additionally, the survey was used to select bipolar adjective items sensitive to user attitudes toward present helmets.

METHOD

Subjects

Seventy-six noncommissioned officers (NCOs), grades E-5 through E-9, served as subjects. The sample was selected from troops assigned to Fort Benning, GA and Aberdeen Proving Ground, MD. Approximately three-fourths of the sample were soldiers with only infantry background, while the remaining men held ordnance military occupational specialties.

Apparatus

Preprinted Equipment Rating Scales with appropriate instructions were presented as a paper-and-pencil survey.

Procedure

The scale was administered initially to a group of 21 NCOs. Ten days later the same scale was administered to the same 21 NCOs for a test/retest reliability evaluation. The scale was administered to a second group of 55 NCOs 14 days after the retest was administered to the first group. The scale was administered to the groups in auditorium settings. Although the instructions were included in the booklet, the test officer read the instructions aloud before the Ss began the survey.

RESULTS

The raw data were evaluated by means of factor analytic procedures (4). Five factors were called for in the program. The factor loadings (data clusters) for the M1 helmet appear in Table 3. A profile of the semantic space for helmets is depicted in Figure 1.

Applying the Pearson Product Moment Correlational Technique to the test/retest data yielded a correlation coefficient of $r = .76$ for the helmet data.

DISCUSSION

Factor I loadings include the items pleasant-unpleasant, large-small, military-unmilitary, comfortable-uncomfortable, and heavy-light. This factor seems to reflect an evaluation of comfort. The item, military-unmilitary, may seem out of place; however, taking into account the military career orientation of the sample, this item is logically placed: a soldier might very well feel uncomfortable wearing a helmet which lacked military identification. Factor II (clean-dirty, necessary-unnecessary, and valuable-worthless) related to the utility of a ballistically protective helmet. The relatively low loading of the item clean-dirty reflects an apparent difference in rating of the sample. Clean-dirty loaded fairly high in three different factors: Factor I -- comfort, Factor II -- utility, and Factor IV -- esthetics.

Factor III is difficult to identify. The high loading of the item stable-unstable would suggest an activity factor; however, good-bad and strong-weak are difficult to link with the concept of activity. Evaluation is further confused by the high loading of fast-slow (clearly an activity item) in Factor IV. The remaining loadings in Factor IV seem to represent an esthetics criteria. Beautiful-ugly, right on-square and sharp-dull all load highest in Factor IV. In Factor V, thick-thin and hot-cold are apparently related only in terms of the physical properties of the M1 helmet.

The results of the factor analysis of helmet ratings suggest that the sample did use systematic criteria to evaluate the equipment in question, but it is also apparent that many of the items used in the scale are so general in nature as to cause deviation from any systematic rating criteria. To further describe regularities which appear to exist in rating criteria, it will be necessary to alter subsequent scales to include items which are more sensitive to the criteria made apparent in this first rating scale. Having described the five factors as I--comfort, II-utility, III--activity, IV--esthetics and V--physical, it is possible to select items more suitable for rating along these criteria. In short, the irregularities which have been cited in factor loading most probably have resulted, not from the technique, but from selection of items included in the first scale. A list of additional items for future development of the scale appears in Appendix B.

It is apparent from this initial effort that there is a strong potential for applying the semantic diffential to the evaluation of ballistic helmets. Once a specific scale has been devised, normative data can be collected by using the existing helmet as the subject equipment. By recording this normative information and operationally defining this data bank as the attitudes toward existing equipment, a point of reference can be achieved. As future prototypes become available, testing can be conducted to determine troop attitudes towards the new hardware.

The crucial test of the technique will be the degree of variance which can be identified when the rating scale is used to compare two or more helmet designs.

TABLE 3

Rotated Factor Matrix, Version 1

	Factor I	Factor II	Factor III	Factor IV	Factor V	h^2	$\overline{X}$
Clean-Dirty	.34	.40	-.05	.37	.15	.44	5.0
Good-Bad	.15	.28	.43	-.00	-.02	.31	5.0
Sharp-Dull	.25	.01	.09	.71	.13	.59	3.7
Beautiful-Ugly	.15	.24	-.12	.80	.00	.75	3.5
Strong-Weak	-.10	.22	.57	-.12	-.06	.40	5.5
Pleasant-Unpleasant	.59	-.09	.14	.50	-.16	.66	3.2
Stable-Unstable	.08	-.07	.76	.19	.11	.64	4.5
Thick-Thin	-.28	-.21	.39	.00	.70	.77	4.8
Large-Small	-.70	-.26	.04	-.07	.03	.57	4.8
Active-Passive	.45	.27	.18	.18	.28	.42	4.6
Military-Unmilitary	-.61	.31	.23	.10	.00	.53	6.2
Comfortable-Uncomfortable	.59	.01	.24	.36	-.11	.55	2.8
Necessary-Unnecessary	-.02	.86	.04	.07	.03	.74	5.8
Heavy-Light	-.71	.07	-.16	-.24	.40	.76	5.9
Valuable-Worthless	-.01	.81	.28	-.04	-.16	.78	5.4
Hot-Cold	-.03	.02	-.38	-.20	.58	.53	4.8
Square-Right On	.10	.04	.38	.45	-.19	.40	4.4
Fast-Slow	.03	-.12	.04	.70	-.34	.62	3.7

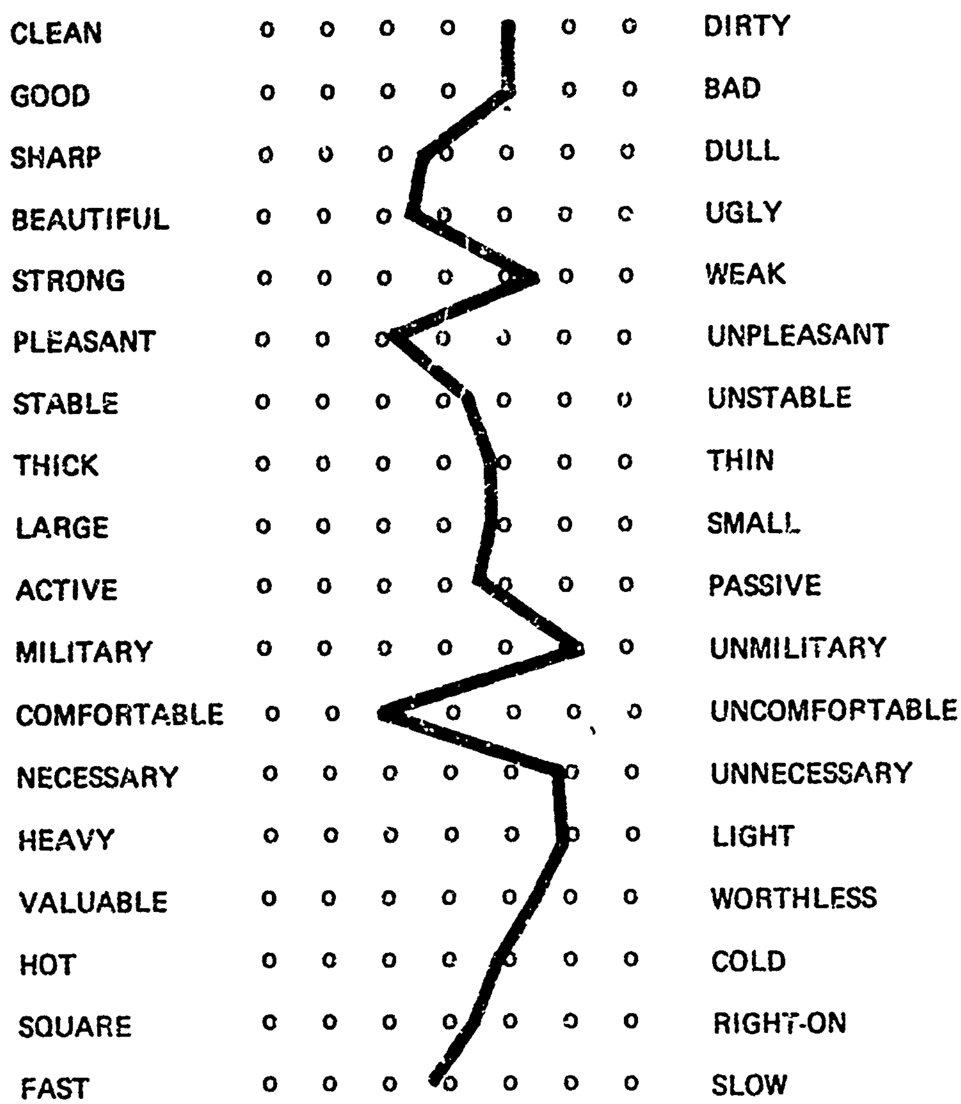

Fig. 1. SEMANTIC PROFILE, VERSION 1

RATING SCALE: VERSION 2

INTRODUCTION

The initial results from the application of rating scales to protective-equipment evaluation suggested that the user population employs some standard criteria in judging equipment quality. To the extent that this conclusion is true, it should be possible to evolve a scale which is sensitive to these criteria.

A second survey was conducted to develop a rating scale sensitive to user criteria for infantry helmets.

METHOD

Subjects

Sixty U. S. Army captains served as subjects. These officers were attending the Infantry Advanced Course at Ft. Benning, GA. All Ss were assigned through the Infantry Branch.

Apparatus

Preprinted Equipment Rating Scales with appropriate instructions were presented as a paper-and-pencil survey.

Procedure

The group completed the survey in a classroom setting. A representative of the U. S. Army Infantry Research and Development Liaison Office at Ft. Benning administered the survey. Instructions were read aloud to the group before the survey was administered. The semantic scales were attached to a forced-choice questionnaire relating to many types of infantry equipment. The combined survey required an average of 10 minutes to complete.

RESULTS

The raw data were evaluated by means of a general factor analysis procedure (4). Three factors were called for in the analysis. The rotated factor matrix appears as Table 4. Figure 2 depicts the semantic profile resulting from the mean scores on each bipolar pair.

TABLE 4

Rotated Factor Matrix, Version 2

	Factor I	Factor II	Factor III	h^2	$\overline{X}$
Heavy-Light	-.07	.73	-.28	.62	1.9
Valuable-Worthless	.84	.07	.00	.70	5.6
Comfortable-Uncomfortable	.08	.76	.15	.61	2.5
Hot-Cool	-.11	.75	.29	.66	2.6
Strong-Weak	.84	-.17	-.13	.75	5.3
Modern-Obsolete	.49	.40	.38	.56	3.4
Loose-Tight	.00	-.04	.90	.83	3.7
Stable-Wobbly	.17	.74	-.10	.59	2.6
Useful-Useless	.82	.19	.08	.71	5.6
Protective-Unprotective	.89	-.04	.06	.80	5.7

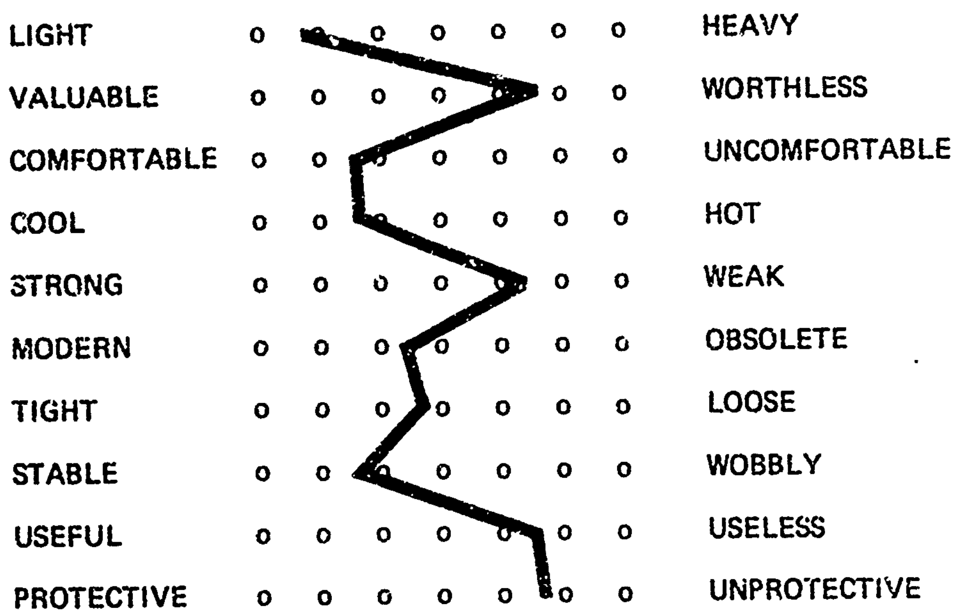

Fig. 2. SEMANTIC PROFILE, VERSION 2

DISCUSSION

Factor I loadings for this scale and subject group were quite high. Valuable-worthless, strong-weak, useful-useless, and protective-unprotective all loaded in Factor I above the .8 level. These items suggest a ballistics factor. When the background, experience and training of a group of company-grade infantry officers are taken into account, the relationships among the Factor I items are easily recognized.

Factor II loadings, while not as strong as Factor I, grouped neatly in a comfort factor. Heavy-light, comfortable-uncomfortable, hot-cool and stable-wobbly are related in terms of the overall sensory stimulation to be expected while wearing a helmet.

The single-item loading in Factor III, tight-loose, represents a fit criterion not seen in previous helmet surveys. A fit criterion would yield valuable design input if it can be developed to a finer degree.

Other interesting effects can be seen in the data from this survey. The item modern-obsolete loaded in all three factors with a range from .39 to .49. Pilot studies have shown that other general items spread across factors rather than loading together as a general evaluative factor. Therefore, such adjective pairs as good-bad, clean-dirty, right on-square and satisfactory-unsatisfactory do not provide a precise meaning to the critical user when more specific adjective pairs are present.

Another interesting effect can be seen in the relationship between factors across officers and noncommissioned officers. The earlier survey using NCOs as subjects yielded a comfort factor (Factor I) and a utility factor (Factor II). These same factors appear in the data for officers but in reversed order, i.e., Factor I - utility and Factor II = comfort. This point is important since it suggests that the sample being surveyed may require stratification or that sampling should be restricted to a sub-population based on rank or responsibility level.

The consideration of sampling from sub-populations is further supported by results of a pilot study conducted the HEL. In this unpublished study, a sample of enlisted men ranging in rank from E-2 through E-8 was surveyed with a rating scale similar to the instrument used for NCOs only. The combined analysis yielded confusing results. Specifically, the items military-unmilitary, good-bad and square-right on loaded in a factor together, but with low values. Later analysis of these data, using only NCO's responses, caused this factor to drop out. The tenuous relationship between these items seemed to result from the differences of opinion between career NCOs and lower-ranking enlisted men as to whether military, good and right-on shared a positive relationship. That is to say, a career man might tend to see things military as being good, while a soldier serving as a result of draft might see military things as bad. These statements are speculative in nature; however, they are an argument for including junior enlisted men, NCOs and officers in the total sample.

Based on the findings of this and previous studies, a third version of a helmet rating scale was prepared. This scale is designed to develop the fit-criteria factor and to consolidate and replicate the comfort, utility and esthetics factors found in past surveys. Since the fit-criteria factor was actually the single item, tight-loose, it is necessary to add additional items which pertain to fit. Such items are difficult to conceive in bipolar adjective form. To describe fit, it is necessary to employ bipolar verb combinations. The items, grips-slides and slips-clings have been added to complement tight-loose. Should these new items load highly with tight-loose, many more bipolar verbs can be introduced in the scale which may add to the utility of the instrument as a subjective measure under dynamic conditions.

RATING SCALE: VERSION 3

Helmet Rating Scale Version 3 was administered to 255 officers and enlisted men at Aberdeen Proving Ground and Ft. Benning, GA. Because the pilot studies suggest that there are systematic differences among junior enlisted men, NCOs and officers, samples were used during the collection of data with Version 3. The sub-samples and the number of cases in each sub-sample is shown in Table 5. The number of cases in each sub-sample was based on availability of troops; however, the background of the sub-sample was determined to allow officer, NCO and junior enlisted men participation of infantry troops, as well as a sampling of officer and enlisted support troop (Ordnance Corps).

Table 6 shows the factor matrix for Version 3. The relationship of factors and the variables loading in the factors are similar to Version 2. Table 7 allows a comparison between those bipolar pairs used on both Version 2 and Version 3.

DISCUSSION

The results of the survey are encouraging since the mean scores and factor loading achieved on Version 3 were predictable from the data collected with Version 2. Prediction of mean scores indicates that the semantic technique is a reliable instrument in assessing user acceptance variables associated with ballistic helmets. The four factors emerged as predicted, with the bipolar verbs loading along with the tight-loose bipolar pair. This factor can now be considered a subjective measure of fit.

From these findings, it can be stated that at least certain aspects of user acceptance of the M1 helmet have been quantified. This allows for direct comparison of candidate helmets with the M1. Such comparisons can be achieved by allowing a sample group to respond to the M1 helmet using Version 3. After experience with a candidate helmet, the same group will again respond to Version 3 for the candidate helmet. The scores can then be analyzed to establish the position of the new helmet relative to the M1.

Several questions remain to be answered. The rating scale is sensitive to user preference, but because there is still no way to directly relate the mean values of the scale to any known physical measurement such as weight, and because face validity of the semantic technique is frequently questioned, it was necessary to conduct an evaluation to determine if the semantic technique is suitable to use as a dependent variable in field evaluation. It is also important to learn what a mean value resulting from the semantic technique means in terms of weight and helmet stability.

TABLE 5

Sub-Samples Used for Version 3

Sub-Sample	Location	No. of Cases
Infantry Officers	Ft. Benning, GA	80
Ordnance Officers	APG, MD	34
Infantry NCO	Ft. Benning, GA	35
Infantry EM	Ft. Benning, GA	49
Ordnance EM	APG, MD	57
Total Infantrymen		164
Total Ordnance Corps		91
Total		255

TABLE 6

Rotated Factor Matrix, Version 3

	Ballistics	Comfort	Age/Rank	Fit	Esthetics	h^2	$\overline{X}$
Necessary-Unnecessary	.74	.03	.06	-.20	.23	.64	2.0
Tight-Loose	-.06	.01	-.14	.72	.32	.64	4.6
Good Looking-Ugly	.24	.40	.01	.09	.52	.51	4.6
Strong-Weak	.62	-.08	.06	.32	-.15	.52	2.7
Slips-Clings	.09	-.25	.10	-.66	.02	.52	2.8
Comfortable-Uncomfortable	.10	.69	.12	.23	.31	.65	5.6
Useful-Useless	.85	.13	.12	.02	.02	.75	2.4
Neat-Sloppy	.40	.33	-.14	.02	.41	.46	4.1
Large-Small	.17	-.53	.25	-.12	-.01	.38	3.0
Protective-Unprotective	.82	.01	.16	.08	.02	.71	2.4
Hot-Cool	-.06	-.74	.10	-.14	.08	.59	2.6
Grips-Slides	.05	.43	-.05	.63	.09	.60	5.0
Stable-Unstable	.19	.46	-.05	.51	.18	.55	5.3
Valuable-Worthless	.79	.00	-;00	-.05	.11	.65	2.9
Heavy-Light	-.02	-.79	-.04	-.11	-.14	.65	2.0
Safe-Dangerous	.76	.02	.12	.25	-.02	.66	2.6
Sharp-Dull	-.05	.02	-.05	.21	.82	.72	4.6
Age	.15	.02	.81	-.17	-.04	.71	23.8
Rank	.15	-.16	.85	-.05	-.04	.77	E6

RATING SCALE VALIDATION

In order to test the rating scale technique in a field study, three helmets – the Hayes-Stewart prototype, a Hayes-Stewart size 9 shell with M1 helmet liner and an M1 helmet -- were presented to Ss under dynamic conditions. The experimental helmets were selected because they differ from the M1 in weight, shape and suspension. (Hayes-Stewart 1.5 lbs, Hayes-Stewart with M1 liner 2.5 lbs and M1 helmet 3 lbs). Although a conventional experiment would evaluate the data to determine differences between helmets, this experiment was developed to investigate the properties of the rating scale. Nevertheless, it was hypothesized that individuals would not be able to recognize differences between the 2.5-lb Hayes-Stewart/M1 liner and the M1 helmet, but that differences between those conditions and the 1.5 lb Hayes-Stewart would be apparent.

Sixteen enlisted infantrymen wore each of the three helmets during dynamic activities. The activities consisted of running, dodging, hurdling and assuming the prone firing position. These exercises required approximately 10 minutes to complete. After each condition the individual was asked to rate his helmet. Individuals participated in each exercise in groups of three. The order of presentation was counterbalanced to distribute experimental error across the three conditions.

The data from this experiment were reduced and analyzed by ANOVA repeated measures (Table 8). Results show a significant difference between helmets ($F = 30.80$ df 2/30 $p < .001$) and bipolar pairs ($F = 2.49$ df 5/ 75 $p < .01$). A significant helmet/bipolar pair interaction is also apparent ($F = 3.23$ df 10/150 $p < .001$).

The mean scores for each bipolar adjective by helmet condition are plotted in Figure 3. A curve presenting the predicted scores for the M1 helmet is also present in Figure 3. The nature of the helmet/bipolar pairs interaction can also be seen.

Examining the results shows that the original hypothesis is not true. Individuals reported differences between the M1 condition, and both the Hayes-Stewart and Hayes-Stewart M1 liner conditions. Very little difference was reported between the latter two conditions. Although a graded response is indicated, the difference between the 1.5 lb and 2.5 lb condition is not statistically significant.

It is apparent that while the M1 helmet was presented as a control, the group could not recognize where the M1 helmet was located in terms of the seven-point rating scale. Locating the M1 on the scale requires too much abstraction on the part of the rater. Therefore, some provision must be made to emphasize the nature of the comparison between helmet conditions. A solution to this problem is to indicate graphically on the rating scale where the M1 helmet should be rated. This could be done by plotting the curve of past M1 helmet responses on the rating scale or by arbitrarily assigning the value of 4 to the M1 helmet. Since plotting the curve on the scale essentially forces the individual to conform to the judgments of an outside group, the method of arbitrarily assigning a value of 4 to the M1 reference is more appropriate. The latter procedure dictates that the M1 helmet control condition must be presented to the subject as an experimental helmet and not as the "M1 helmet." If the individual rates the M1 helmet, thus presented at the level of 4 on all bipolar pairs, experimental control can be assumed. If, on the other hand, an individual rates the M1 helmet at values other than 4, the experimenter has an indication of experimental error. Anchoring responses of the M1 helmet to 4 on the scale forces the individual to compare each helmet condition to the M1 helmet.

TABLE 7

Comparison of Mean Values, Versions 2 and 3

	$\overline{X}$ Version 2	$\overline{X}$ Version 3	Difference
Tight-Loose	4.6	4.3	0.3
Strong-Weak	2.7	2.7	0
Comfortable-Uncomfortable	5.5	5.6	0.1
Useful-Useless	2.4	2.4	0
Protective-Unprotective	2.3	2.4	0.1
Hot-Cool	2.6	2.6	0
Stable-Wobbly	5.4	5.3	0.1
Valuable-Worthless	2.4	2.9	0.5
Heavy-Light	1.9	2.0	0.1

TABLE 8

Results of ANOVA, Hayes-Stewart, Hayes-Stewart
With Liner and M1 Helmets

Source of Variation	SS	DF	MS	F
Between Subjects	167.1667	15		
Subj W. Groups (Error (A))	167.1667	15	11.14444	
Within Subjects	837.4444	272		
B	313.4653	2	156.73264	30.80319
B x Subj W. Groups (Error (B))	152.6458	30	5.08819	
C	13.1111	5	2.62222	2.48945
C x Subj W. Groups (Error (C))	79.0000	75	1.05333	2.48945
BC	49.5347	10	4.95347	3.23492
BC x Subj. W. Groups (Error (BC))	229.6875	150	1.53125	

Figure 3 shows the relationship between experimentally-derived responses during dynamic conditions using 16 subjects and a prediction of responses based on data collected with Version 3 in a classroom setting using 255 subjects. It is interesting to note that only the bipolar pairs directly associated with movement (slips-clings and sloppy-neat) are different from the predicted values.

It can be concluded from the results of this experiment that rating scales are effective in determining difference in helmets during dynamic conditions; however, additional control procedures are necessary to force comparison between a candidate helmet and the M1 reference.

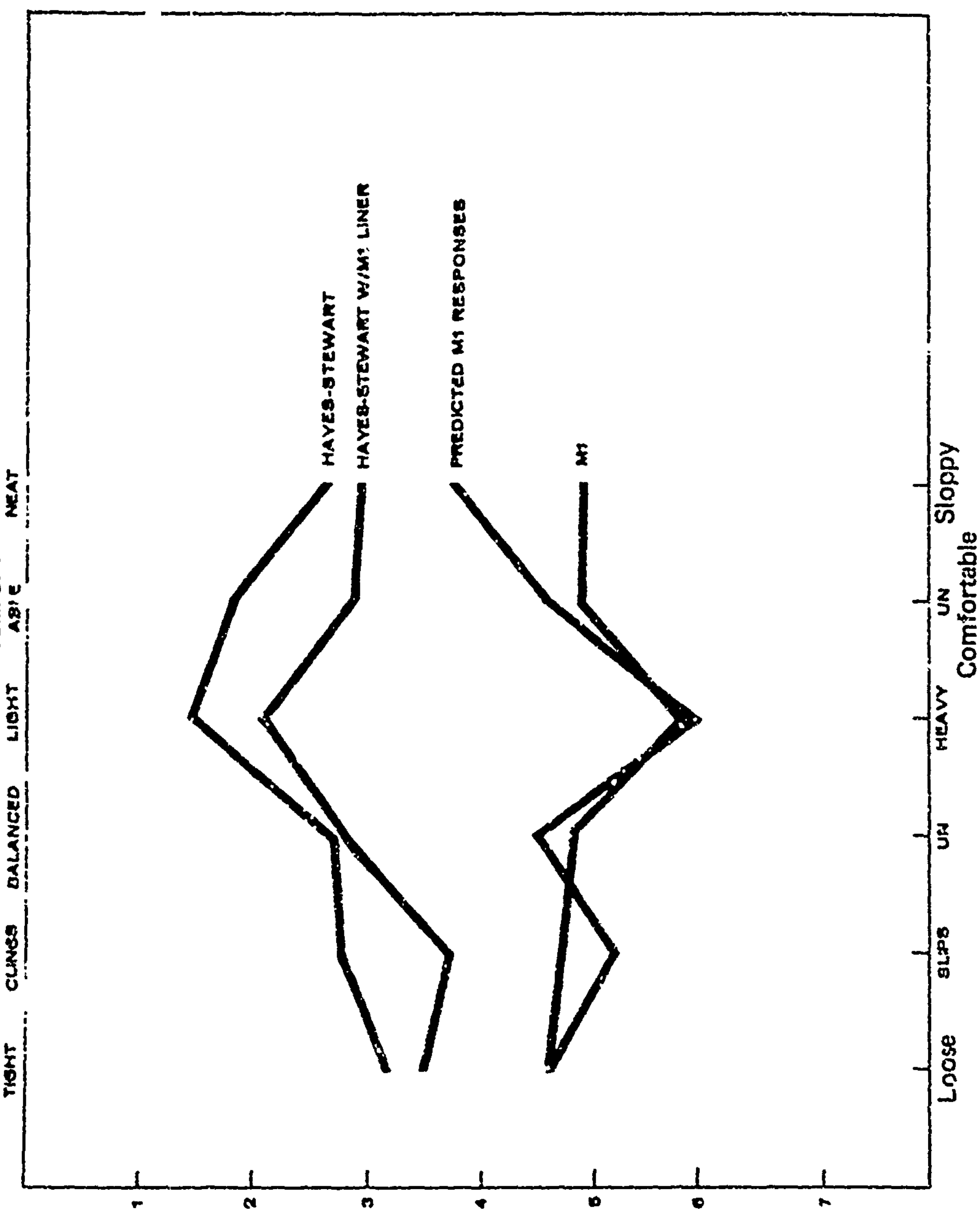

Fig. 3. SEMANTIC PROFILES OF HAYES-STEWART, HAYES-STEWART WITH LINER AND M1 HELMETS

INCREMENTAL HELMET WEIGHT

INTRODUCTION

As stated earlier, the primary purpose of developing a reliable helmet rating scale was to provide a tool for comparing candidate helmets to a known reference, the M1 helmet. Repeated revision and sampling has provided the basic tool. Now, it is necessary to apply the tool in a manner which will be useful during field testing.

The shape of a given helmet confounds efforts of direct comparison unless the candidate helmet is approximately the same weight as the M1 reference helmet. Therefore, it is necessary to learn something about helmets over varying weights, but similar in shape. Collecting data on M1-like helmets of varied weight allows the experimenter to state that a candidate helmet is equivalent to an M1 helmet of X number of pounds.

METHOD

To collect data on helmets similar to the M1, but differing in weight, HEL fabricated 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 and 4.5-pound M1-shaped helmets. These experimental devices were constructed of rolled lead and mounted on M1 helmet liners. Each device was covered by a standard camouflage cover so that the external appearance of each was similar. Every effort was made to restrict perceptual cues to the weight of the helmet alone.

Subjects and Procedure

Twenty-two enlisted infantrymen were required to wear each of the seven helmets for two hours at a time. The seven conditions were presented over a period of three and a half duty days. During each presentation the Ss performed duty-type activities. Typically, the Ss participated in other experiments, assisted the experimenters, or awaited additional participation. After the two-hour wearing period, each man rated the experimental helmet.

The rating scale used in this experiment was adapted from Helmet Rating Scale, Version 3. Six bipolar adjectives were selected from Version 3. Of the six, three were comfort indicators and three were fit indicators.

The purpose of this experiment was to develop a comparison between the M1 helmet and helmets similar to the M1 in shape, but of different weights. To assist the Ss in this comparison, the center of the scale (point 4) was established as representing the M1 helmet by providing a line down the center of the scale and indicating this line as the M1 helmet reference. Ss were instructed to express their comparisons from this M1 reference line.

RESULTS AND DISCUSSION

It was hypothesized that the data collected in this manner would describe a curve representing the subjective comparison of the seven weight increments to the M1. This curve would be anchored at the level of four on the scale since the 3-pound helmet condition was in f. .t an M1 helmet.

The data were reduced and the mean scores for each bipolar adjective were plotted with the weight increments as the ordinate and the seven-point scale as the absicca (Figs. 4-9). Additionally, scores for the three-pound condition were evaluated to determine if the group was able to perceive the three-pound condition as an M1 helmet. The results for heavy-light were also adjusted, according to the results of Helmet Scale, Version 3, to describe a curve which equates the present results to what is known about the M1 helmet (Fig. 5).

Figure 4 depicts a psychophysical curve for weight (heavy-light) which closely resembles the curves presented in Jones et al. (6). While the calculated just noticeable differences (JND) of the reference curve are somewhat more extreme than the values evident using the rating scales, the overall curves have similar characteristics. This similarity is probably the result of providing the subject an opportunity to wear each helmet longer under dynamic conditions and also of providing a rating scale in place of simple heavier or lighter responses. Nevertheless, comparison of the two curves indicates that an area of indecision does exist and that the rating scale provides the S with a reasonable method of expressing his particular sensations.

Figures 4 and 6 show that Ss responding to comfort indicators (heavy-light, comfortable-uncomfortable and balanced-unbalanced) expressed a direct relationship between the three variables at the middle weight ranges. This direct relationship breaks down at low and high ranges. The weight variable produced a curve which is linear in nature from the 2.5-pound level up. On the other hand, the comfort variable produced a curve which levels off under 2.5 pounds. This leveling causes an intersect with the weight curve at approximately 2-3/8 pounds.

The curve representing responses for heavy-light must be considered in light of other subjective information about the M1 helmet (15). Infantrymen consistently state the M1 helmet is "too heavy." Repeated surveys using rating scales show a mean value of two for the M1 helmet on the heavy-light bipolar pair. Therefore, a mean value of two really means "too heavy." A value of two is verbalized as moderately heavy. However, in this experiment the subject was directed to rate the variously weighted helmets with respect to the M1 reference value of four on the rating scale. This means that the rating scale is shifted to the high side. Figure 5 shows a plot of the response for heavy-light, adjusted so that the M1 reference is now placed at its previously determined mean value of two. (For the reader's convenience, the curve has been inverted so that the M1 value is two scaling units above instead of two units below the center point on the scale.)

If the empirically determined value for the M1 represents a judgment of "too heavy," it is reasonable to assume that some point on the curve (Fig. 5) represents a judgment of "too light." However, it would be an error to attempt to say that a point equal and opposite to the point representing "too heavy" is the point of "too light." In fact, since ballistic protection is a function of weight, the point of interest on this curve is the point where weight is not a consideration. Since the value of four on the rating scale is a neutral or no opinion judgment, that point shows the best weight for a helmet shaped like an M1. Consulting the curve we see the weight value associated with the scale value of four is slightly over two pounds.

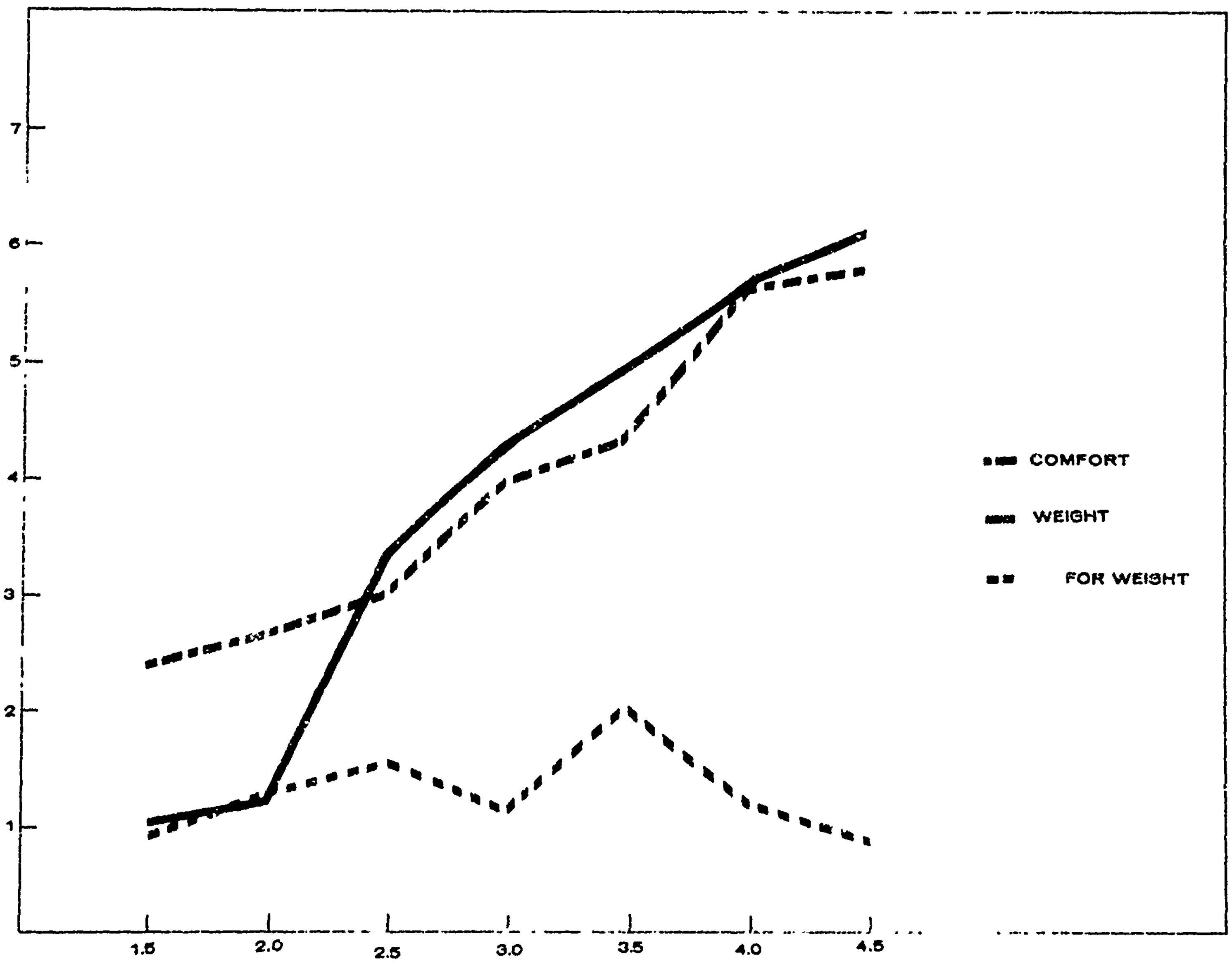

Fig. 4. RESULTS OF RATING SCALES (HEAVY-LIGHT/
COMFORTABLE UNCOMFORTABLE)

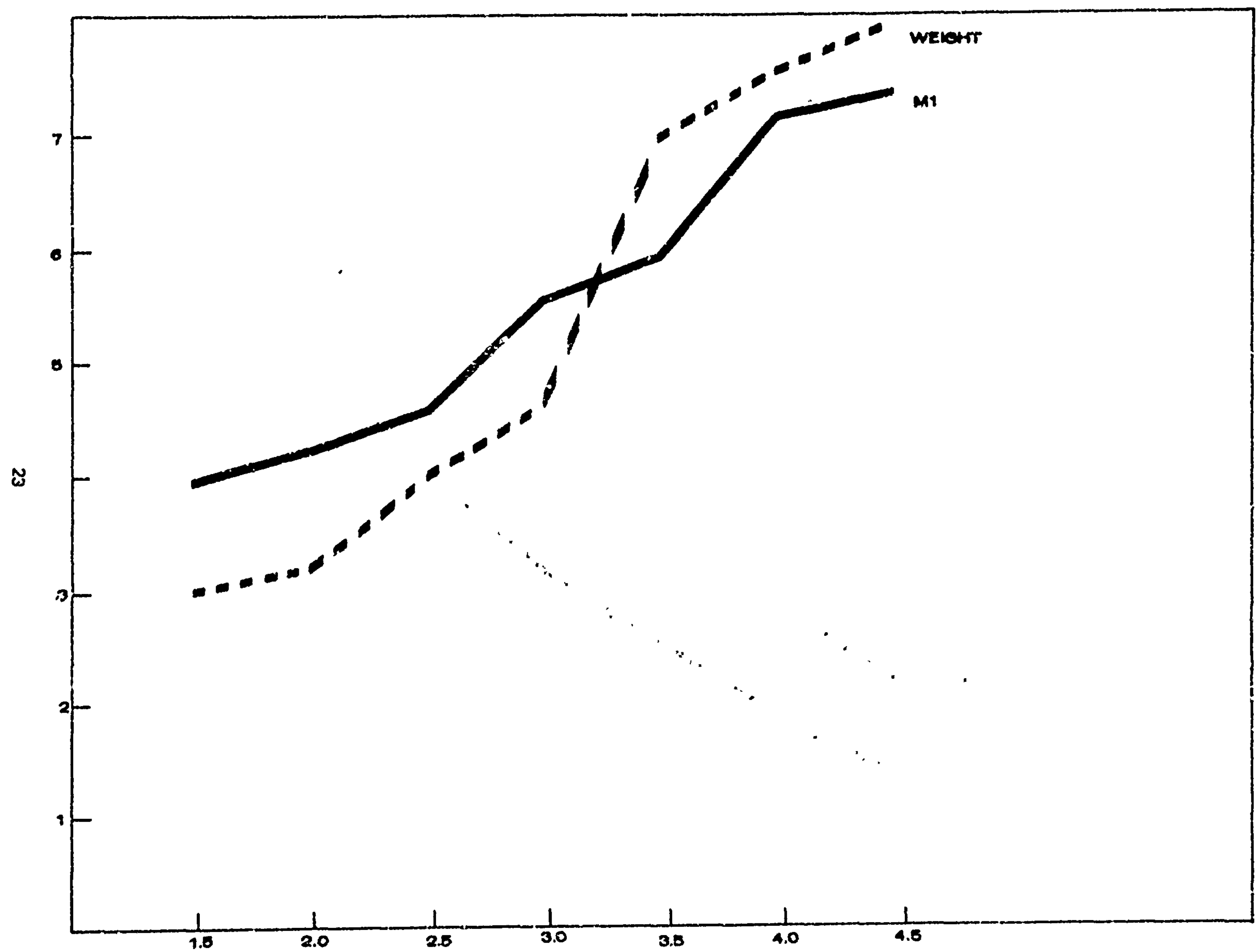

Fig. 5. RATING SCALE RESULTS (ADJUSTED)

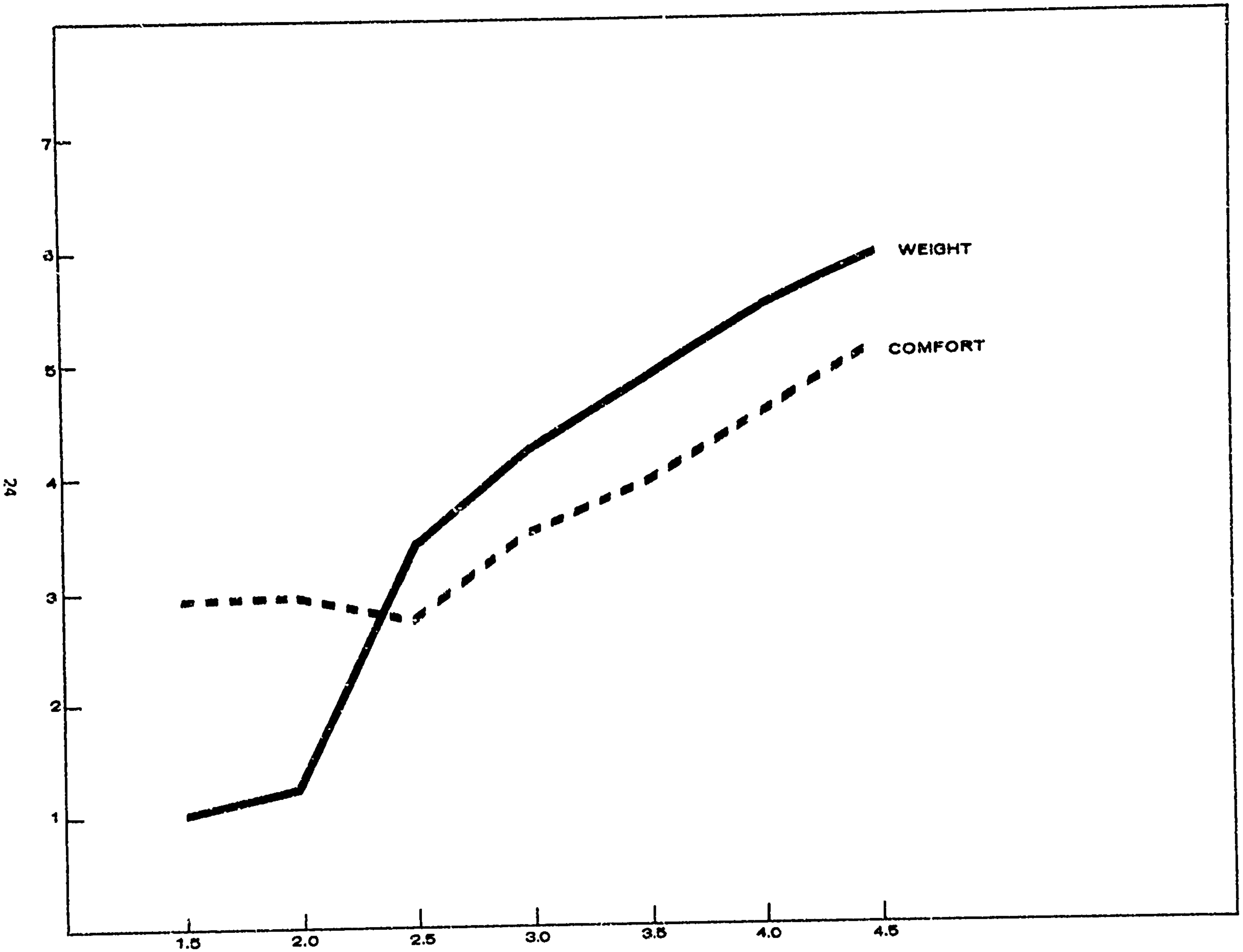

Fig. 6. RATING SCALE RESULTS (HEAVY-LIGHT/ BALANCED-UNBALANCED)

Weight was the only parameter systematically altered during this experiment; therefore, the ratings for all other variables were influenced by physical weight. Figures 6 through 9 show the relationship of each of the remaining bipolar pairs to weight.

The plot for heavy-light and comfortable-uncomfortable are the most important curves. The curve is adjusted to the values obtained from Version 3. The adjusting value for comfort is 1.5 scaling units. Examining the comfort curve, it can be seen that below 2.5 pounds the slope of the curve decreases. This causes an intersect with the heavy-light curve between 2.0 and 2.5 pounds. In other words, under 2.5 pounds the reduction of a unit of weight is not as effective in terms of comfort as similar reductions at higher helmet weights. Because of this effect it can be said that the optimum weight for an M1-like helmet with liner is between 2.0 and 2.5 pounds.

The causes for the leveling off of the comfort curve are impossible to determine from the present research. However, one can speculate as to the reasons for this shift. The Ss were asked to rate ballistic protective helmets. Past research indicates that infantrymen place high value on the ballistic characteristics of the helmet. Since comfort is a concept normally associated with a general feeling of well-being, it is conceivable that these Ss did not believe that the lighterweight helmets would provide adequate ballistic protection. In a sense, the leveling off of the comfort curve may be associated with the feeling of "too light." If this is the case, it indicates a potential need for indoctrination and demonstration of the ballistic characteristics of future lightweight helmets to the using population.

The standard deviations of the distribution of scores for heavy-light are representative of the amount of indecision displayed by the sample at a given incremental weight. Testing each weight for difference from the standard deviation calculated for the M1 shows that only the 2.5-pound and 3.5-pound conditions are significantly different. It is clear that the threshold for weight differences can be found between 2.5 and 2.0 pounds for weights below 3 pounds and between 3.5 and 4.0 pounds above the M1 reference. This finding again suggests that helmets of the M1 shape should be designed within the weights of 2.0 and 2.5 pounds. This range will provide a perceived lightening in weight at the highest ballistic mass. The distribution of standard deviations are plotted below the reference curves on Figure 4. Table 9 provides a tabular listing of standard deviations and standard errors for the distribution of responses for heavy-light.

TABLE 9

Heavy-Light Standard Deviations

Pounds	σ	SE	Significance
1.5	.9	.19	NS
2.0	1.25	.27	NS
2.5	1.49	.32	*
3.0	1.11	.23	
3.5	1.43	.30	*
4.0	1.11	.23	NS
4.5	.8	.17	NS

NS - Not Significant
* - < .05

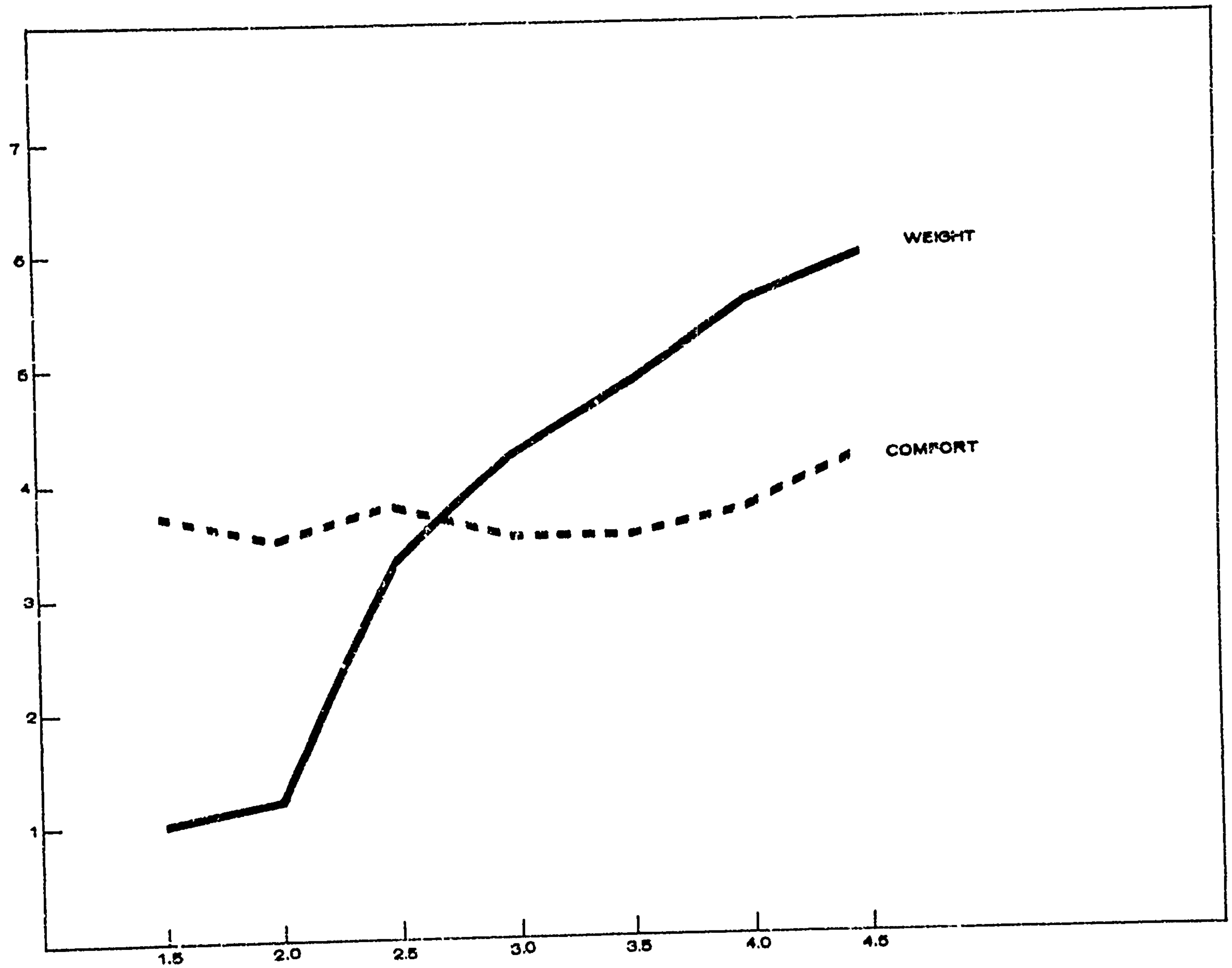

Fig. 7. RATING SCALE RESULTS (HEAVY-LIGHT/TIGHT-LOOSE)

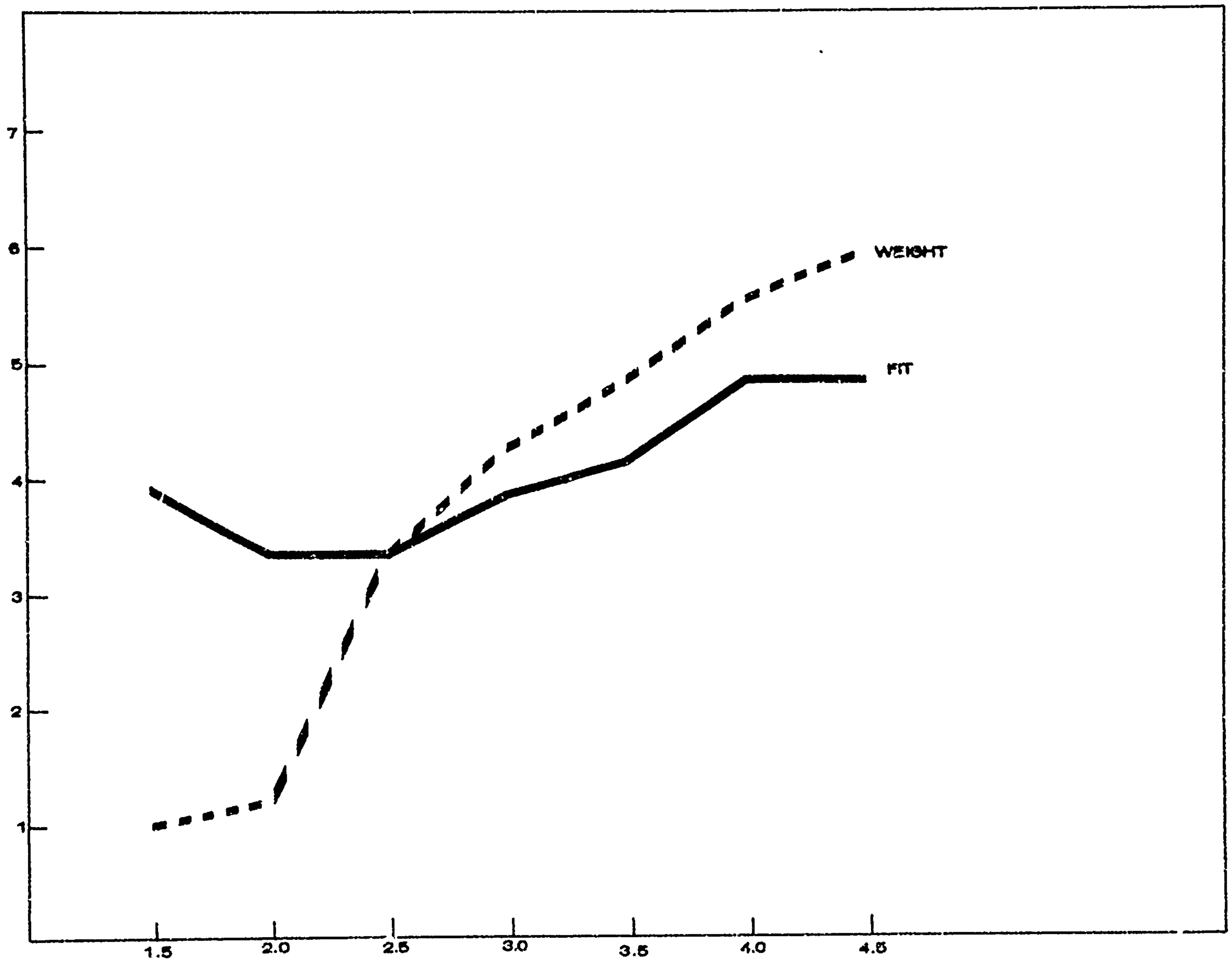

Fig. 8. RATING SCALE RESULTS (HEAVY-LIGHT/SLIPS-CLINGS)

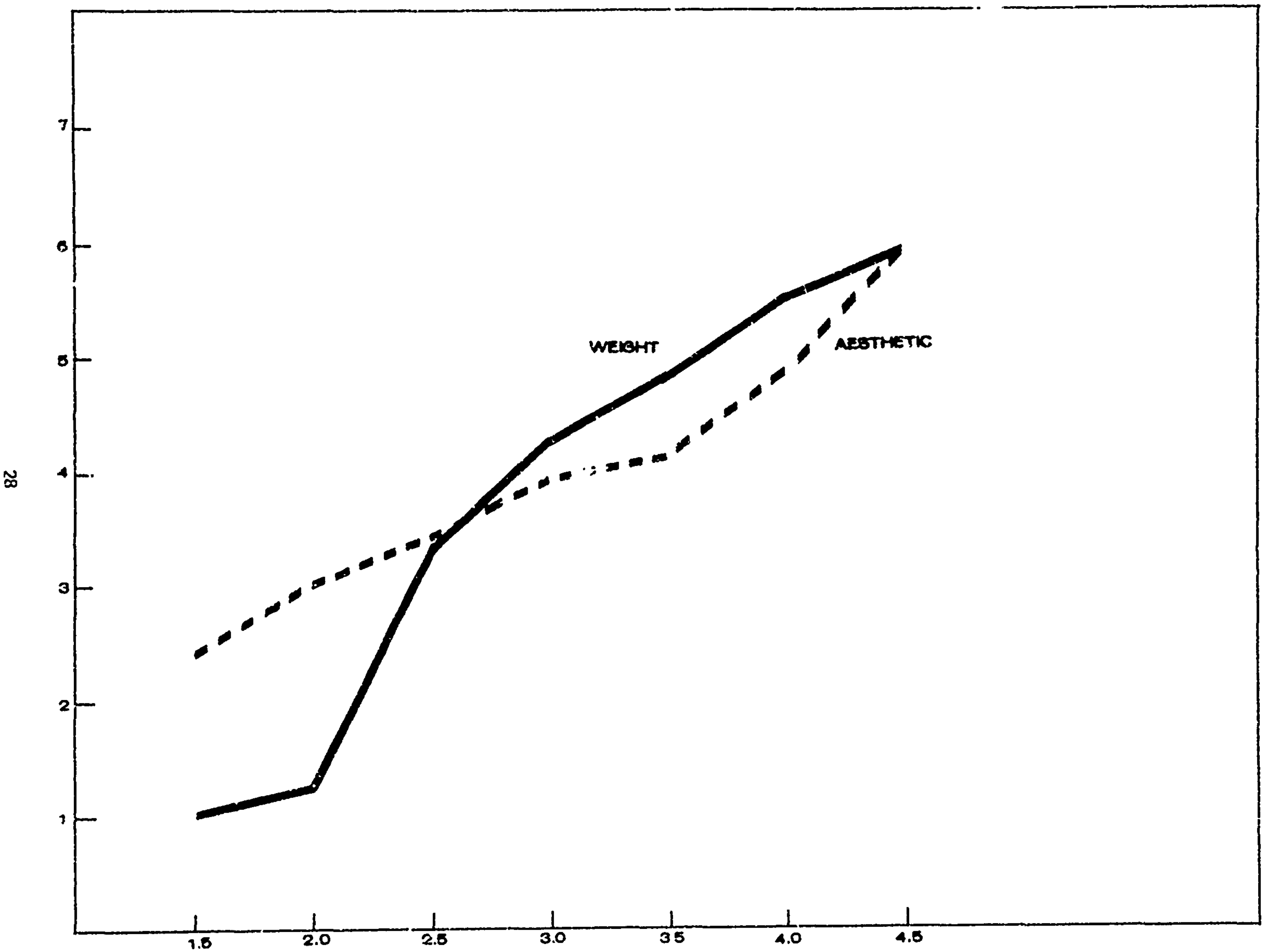

Fig. 9. RATING SCALE RESULTS (HEAVY-LIGHT/SLOPPY-NEAT)

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The purpose of the present research was two-fold. One purpose was to provide design guidance for future infantry helmets. The second purpose was to develop methodology for assessing candidate helmets from a human factors engineering point of view. Other aspects of the human factors considerations in ballistic helmets, such as acoustics, anthropometrics and historical documentation, have been treated separately (5, 9, 10).

DESIGN GUIDANCE

The results of the present research and observation suggest several points of guidance in developing new helmet designs. Some of the HFE inputs are specific while others are conceptual in nature.

1. The weight of a given helmet must be viewed in terms of weight distribution and suspension. The objective of weight reduction must be defined. While physiological considerations are extremely important, the basic thrust of helmet weight reduction must be oriented towards supplying the user with the most effective ballistic protection possible while allowing him to recognize a reduction in weight from the present helmet. If skillful design allows a 3-pound helmet that is recognized as more comfortable and lighter than the present helmet, then that 3-pound helmet is acceptable.

The total weight of a helmet system should also be considered in terms of overall ballistic coverage. The present M1 helmet has a ballistically protective sun visor and rain shield. This seems an inefficient use of weight and ballistic protection. However, present research suggests that removing the visor and rain shield would cause the present helmet to be unbalanced to the rear. Nevertheless, helmet design must provide a perceptually-balanced helmet/suspension system which utilizes ballistic materials for ballistic protection.

The present research indicates that the best tradeoff weight for M1-liner helmets is between 2.0 and 2.5 pounds. That being the case, future candidate helmets should be perceived as lighter than a 2.5-pound M1 helmet (the nature of this comparison will be discussed with methodology.).

2. While no data on suspension systems are presented in this report, the HEL staff has gained considerable experience in fitting and adjusting helmet suspension systems. This experience leads to the conclusion that attempting to adequately adjust helmet suspensions off the head is virtually impossible with the present M1 suspension system. Therefore, some helmet-on adjustment system should be provided. Several options are available ranging from quick-release clamps to drawstrings.

The on-head adjustment concept was considered at HEL and found to be satisfactory. In fact, several persons wearing on-head adjusted helemts without chin straps have been able to perform hand-stands without losing the helmet. While this example is extreme, it points out the need for innovation in the area of helmet suspension/retention.

3. Experience with helmet fitting and anthropometric data make it clear that a sized helmet system is mandatory. Several infantrymen who served as subjects could not be ballistically fitted with the present M1 helmet; that is to say, it was obvious on certain men that very little helmet-to-head standoff was provided. These men were satisfied with the fit of the helmet because the lack of standoff provided a very stable device during dynamic circumstances. Nevertheless, it is clear that these men have a higher probability of becoming casualties than their fellow soldiers.

Additional evidence is available from a study of the M1 and titanium infantry helmets conducted in order to estimate the magnitude of the misfit problem.

The assumptions in this analysis were:

a. Ballistic Standoff (around the entire head)

(1) M1 .75"

(2) Titanium .375"

b. Suspension System Bulk (not including mounting studs)

(1) Length .28" ea. side, Total .56"

(2) Height .28" top, Total .28"

c. Cold Weather Cap (worn w/suspension system)

(1) Length .375" ea. side, Total .75"

(2) Width .375" ea. side, Total .75"

(3) Height .375" top, Total .375".

The interior helmet physical measurements (space available) are defined as follows:

a. Length - fore/aft center line measured from suspension mounting stud to suspension mounting stud.

b. Width - left/right at widest points.

c. Height - center top to suspension mounting studs circumferential center line.

d. Circumference - at suspension mounting studs circumferential center line.

Two helmets were used in this analysis:

a. Helmet, Steel M1, Ballistic Nylon Liner w/Removable Riddell Suspension System.

b. Helmet, Titanium (32 oz), w/Removable Riddell Suspension System (no liner required).

The comparative physical measures of the two helmets are as follows:

TABLE 10

Physical Measurements, Titanium Helmet Without Liner

Measure	B	-SO	-SUS	-CWC	
1. Length @	22.20	20.30	18.90	17.00	CM
	8.74	7.90	7.44	6.69	IN.
2. Width @	19.65	17.75	16.35	14.45	CM
	7.73	6.99	6.44	5.69	IN.
3. Height @	13.90	12.95	12.65	11.70	CM
	5.47	5.10	4.98	4.61	IN.
4. Circum @ Crown	66.70	------	------	------	CM
	26.25	------	------	------	IN.

TABLE 11

Physical Measurements, M1 Steel Helmet With Liner

Measure	B	-SO	-SUS	-CWC	
1. Length @	22.16	18.78	17.38	15.48	CM
	8.72	7.40	6.84	6.10	IN.
2. Width @	20.90	17.08	15.68	13.78	CM
	8.22	6.72	6.17	5.43	IN.
3. Height @	14.00	12.09	11.79	10.84	CM
	5.51	4.76	4.64	4.27	IN.
4. Circum @ Crown	64.70	------	------	------	CM
	25.47	------	------	------	IN.

Key:

B : Basic Shell w/o Suspension System
SO : Stand-off (Ballistic)
SUS : Suspension System
CWC : Cold Weather Cap

Comparing the bar graphs (Figs. 10, 11, 12) makes it readily apparent that neither helmet will accommodate the current population and maintain ballistic standoff. The titanium shell in this regard does have a slight advantage, basically because of the reduced standoff required. It is obvious that soldiers are accommodated by the M1 helmet, but the level of protection is reduced for individuals with large heads.

4. During the testing associated with the present research it became obvious that the length of the soldier's hair influenced the helmet. In particular, soldiers wearing Afro-type hair styles experienced difficulty in suspension adjustment and helmet retention. If soldiers continue to wear longer hair styles, the number of larger-size helmets will be high. If hair styles change, the services will be stocking large supplies of large-sized helmets, but the proper size-to-population ratio will be difficult to maintain. Present guidance states that the length of the hair will not interfere with wearing military headgear. The suggestion is that design of a sized helmet system is confounded by present hair styles. If styles or regulations change after development of the sized system, the services will be faced with poorly fitted helmets.

5. Field feedback (15) indicates that there is a high incidence of headaches associated with wearing the M1 helmet. This effect was observed throughout the testing at HEL. Future helmets should be evaluated to determine if headaches result from prolonged wearing. It is unreasonable to ask a soldier to wear a helmet which causes headaches after two hours wearing time. Of the 22 Ss tested in the incremental helmet weight experiment, 14 reported headaches at least once. It is not clear that weight in the ranges tested directly relates to headaches. It should be pointed out that it was not the intent of HEL to collect data regarding headaches resulting from wearing helmets. In fact, the realization that a high incident of headaches had occurred was reported by the Ss after the fact.

6. Retention of the helmet is a problem. Any helmet selected to replace the present device must not interfere with small arms employment. The present helmet interacts with the back when the soldier is in prone firing position. This interaction occurs on approximately 60 percent of the men observed (11). When the interaction occurs, the helmet either pivots forward (covering the man's eyes) or the forward area of the head band leaves the head, so that the man must readjust the helmet. Many soldiers have learned to place the helmet on the head backwards so the visor is oriented to the rear. This action generally solves the problem for the soldier and may provide guidance to designers of future helmets.

The helmet frequently leaves the head when a soldier quickly assumes the prone firing position. If the chin strap is fastened, the helmet will be retained; however, disorientation of the helmet almost always occurs, with or without the chin strap. This disorientation requires the soldier to readjust the helmet. Future candidate helmets must be stabilized and retained. The lack of stability and retention of infantry helmets is the source of much irritation in the infantry community (15). The importance of significant improvements in this area cannot be overestimated. Providing on-head adjustments may reduce the frequency of occurrence of helmet disorientation.

7. Considerable guidance regarding suspension can be found in the Cornell Aeronautical Laboratories report on combat helmets (1). The recommendations for suspension design put forth in this document are extremely promising.

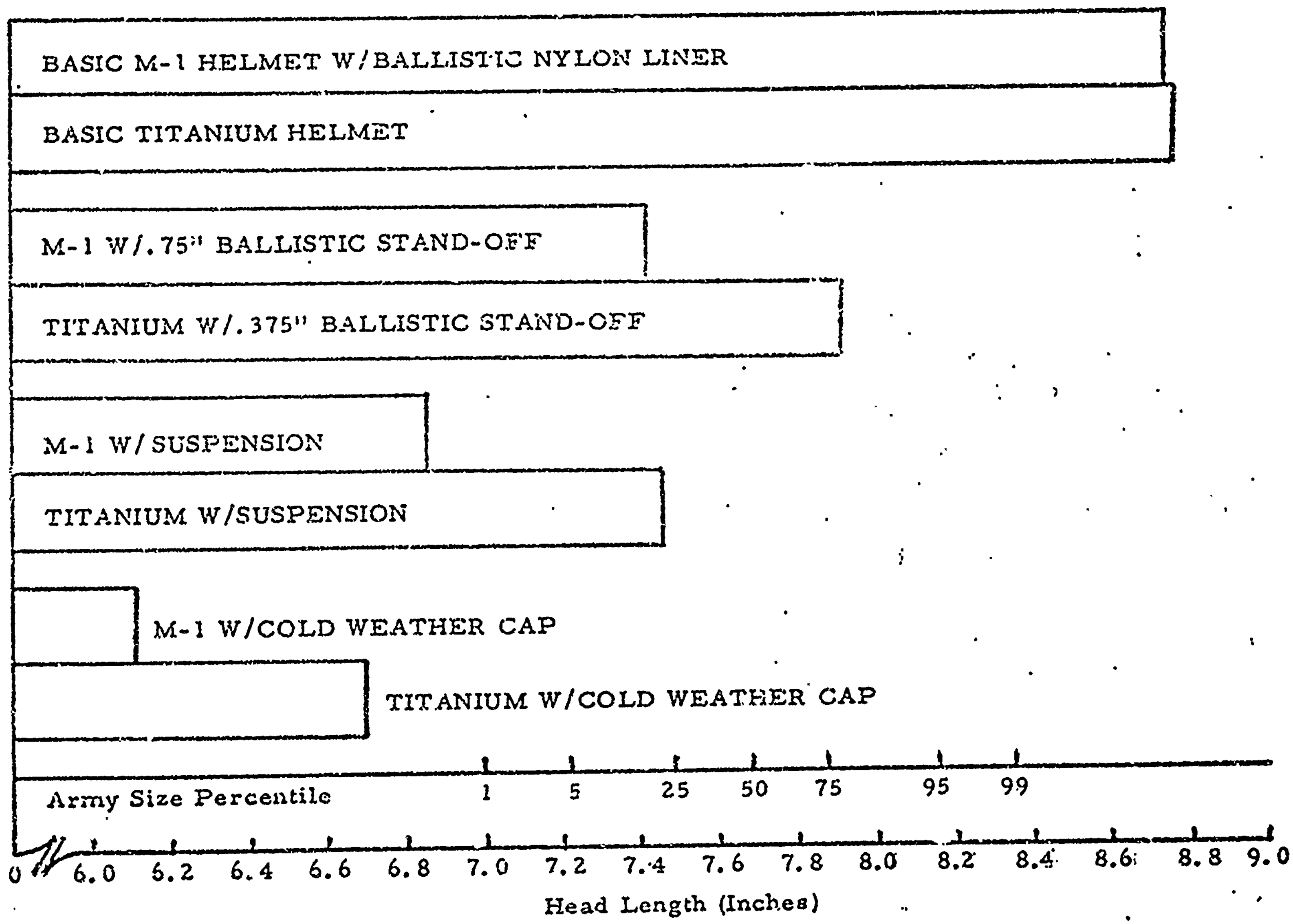

Fig. 10. HEAD LENGTH COMPARISON

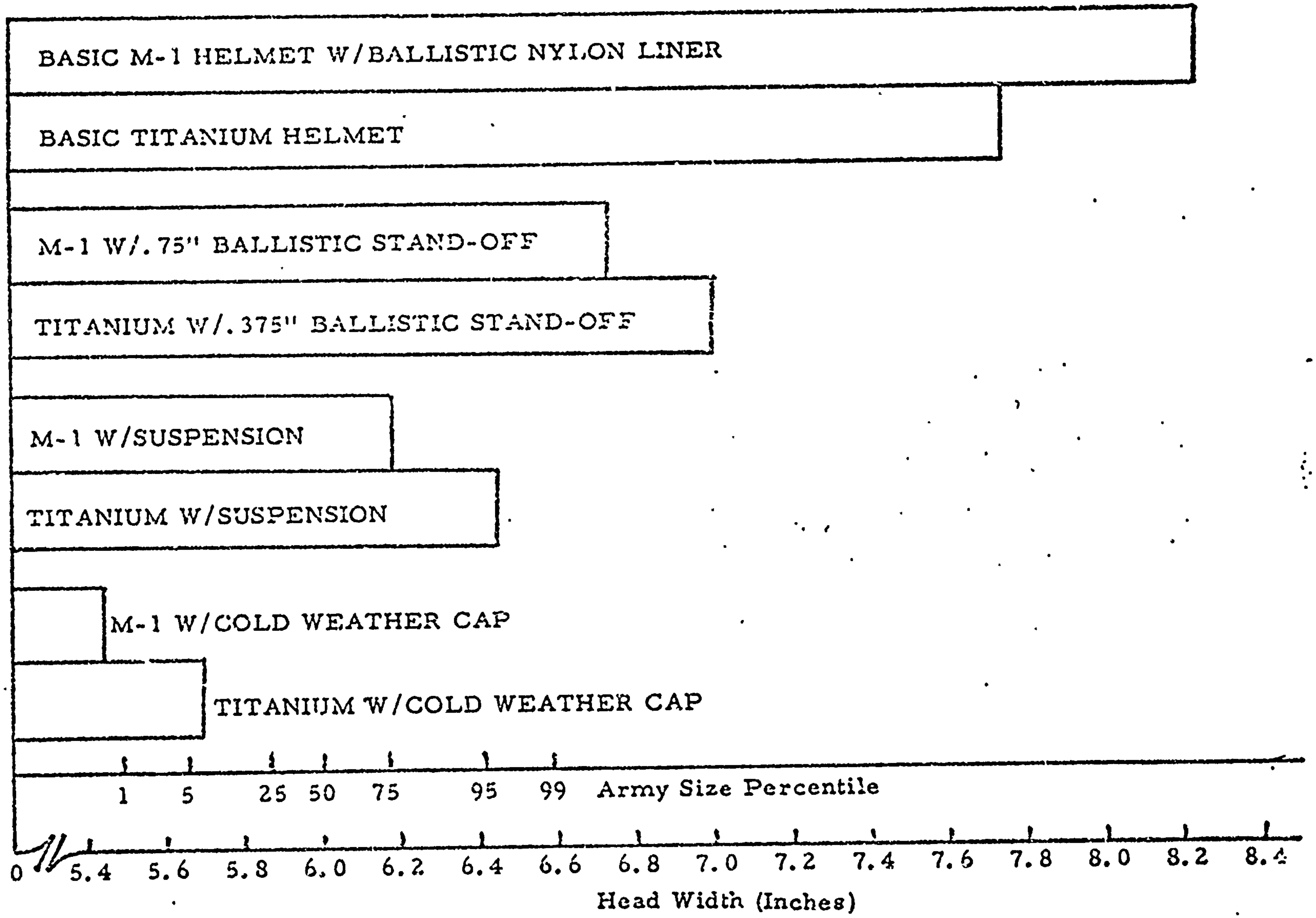

Fig. 11. HEAD WIDTH COMPARISON

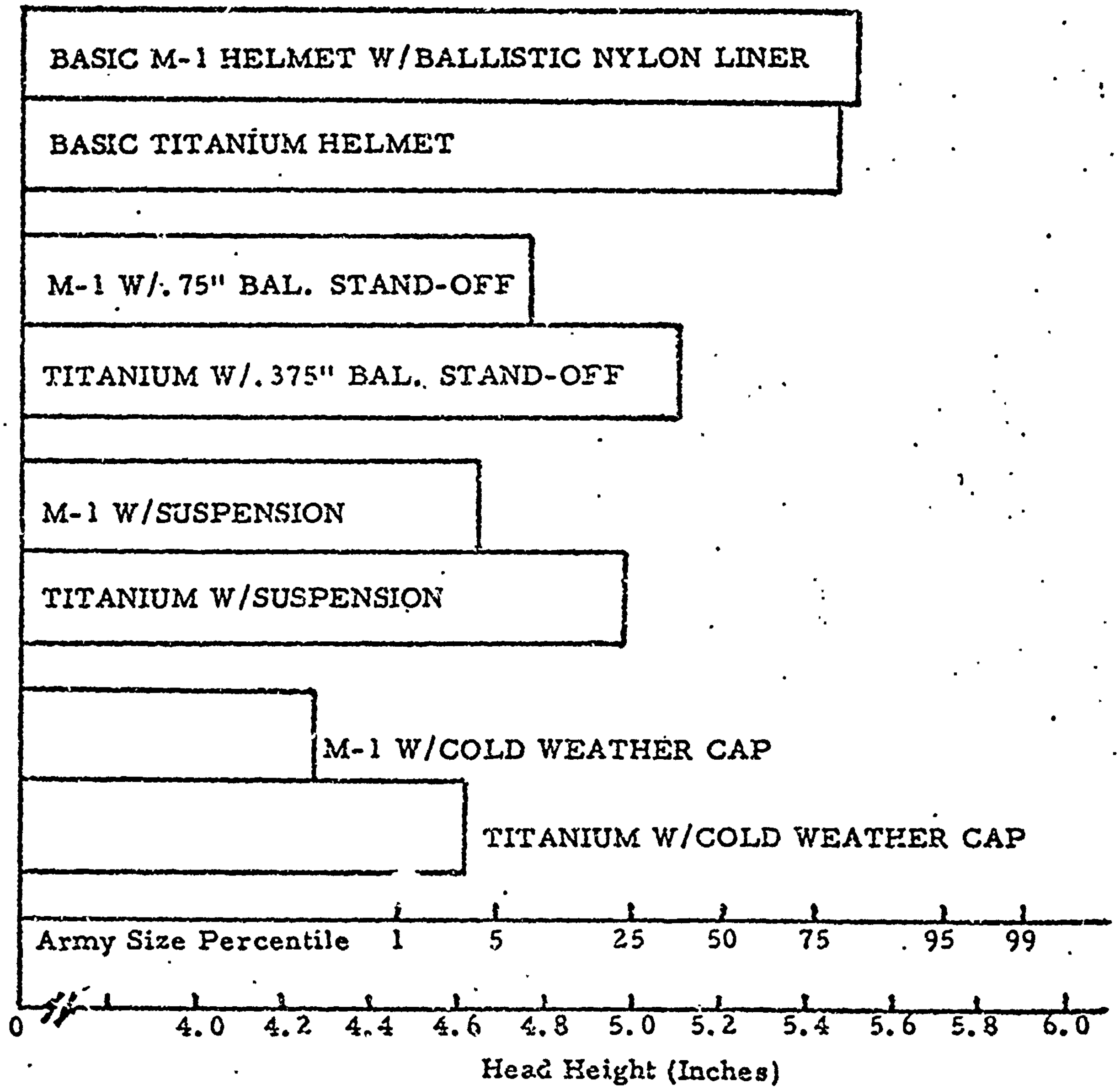

Fig. 12. HEAD HEIGHT COMPARISON

METHODOLOGY

Future candidate helmets should be evaluated for human factors acceptability according to the following procedures:

1. Candidate helmets should be worn by Ss during testing conducted at the HEL Mobility/Portability Course, APG (13). Each S should negotiate the course with each helmet. He should rate each helmet by scales selected from Version 3. The S should also wear the M1 during the testing. The M1 should be presented as another experimental helmet. Each S should also complete a survey of his impression for all candidate helmets. The data resulting from the scales should be plotted against the curve presented in Figure 4. The mean scores for the candidate helmet must fall below the level on the curve representing the 2.5 M1 helmet to be considered an acceptable replacement for the M1 helmet. The survey data should be available for determining more specific information regarding edgecut, suspension adjustment, etc.

2. Subjects should fire the M-16 rifle and the M-60 machine gun at pop-up type targets and the accuracy of fire and time-to-fire should be recorded. Motion pictures of each S during firing should be collected. Data should be reduced and analyzed according to the procedures described by Corona et al. (2).

3. Fitting studies should be conducted to determine if adequate sizing criteria has been applied to the candidate helmet.

4. During the testing cited in 1 above, the retention of the helmet should be monitored by direct observation and by motion pictures or video tape. The nature and frequency of each disorientation of the helmet should be noted. These problems should be reported in terms of specific events on the course, (low crawl, assume prone firing position, foxhole digging, etc.).

5. Testing of the acoustical properties of the helmet should be conducted according to the procedures described by Randall and Holland (9, 10).

6. The visual field of each helmet should be determined according to procedures which are presently being evaluated.

7. Compatibility analysis should be conducted with the following equipment:

a. Small arms

b. Crew-served weapons

c. Protective masks

d. Communications equipment

e. Goggles

f. Arctic masks

g. Load-bearing equipment

h. Body armor

i. Field jacket with hood

j. Selected tactical vehicles

Throughout the testing the M1 helmet should be used as the control device.

8. Test Ss should be organized into a consumer panel after the testing. The purpose of the panel would be to allow the men to verbalize their likes and dislikes about each helmet. The discussions should be recorded and considered in light of all other data collected (11).

9. The data for each helmet should be analyzed and interpreted together, and recommendations for improvements and suitability should be provided to interested agencies.

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